TARDEC Hybrid Electric Program Last Decade

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Army Hybrid Electric Vehicles

FY 98 99 00 01 02 03 04 05 06 07 08 09

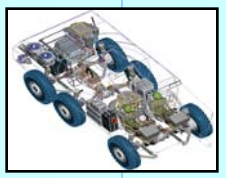
Combat Vehicle Demos


M113 HE


Lancer


AHED 8x8

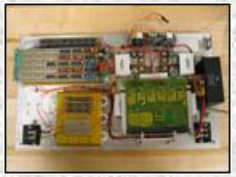

Pegasus

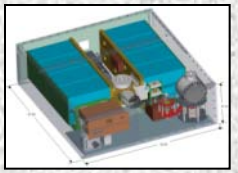

FCS

Technology Base


Traction Motors


Energy Storage

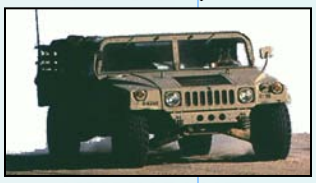

SiC Inverters/ Converters


Pulse Technology


Alternative Architectures


Modeling and Simulation

Tactical Vehicles

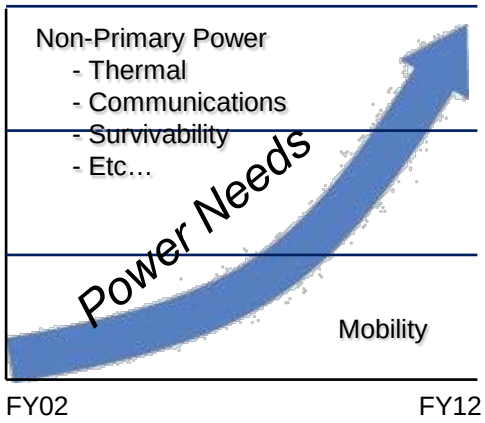

HMMWV HE

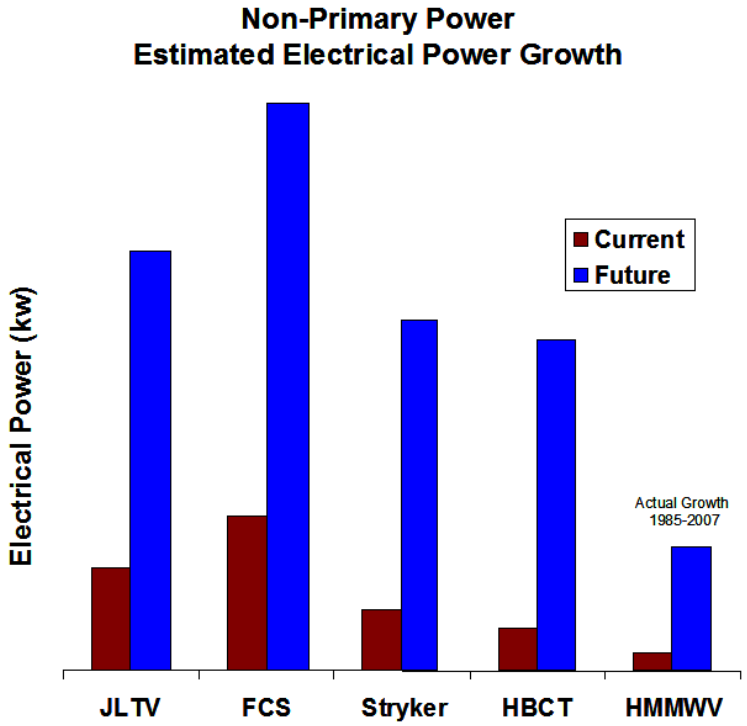

FMTV HE


RSTV


FTTS

Ground Vehicle Power Needs





TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

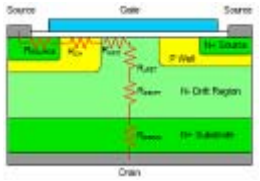
Hybrid Vehicle Challenges

Unprecedented use of emerging technologies never proven in battle field scenarios

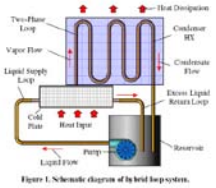
- System integration and packaging
  - ➢ Power densities of components
    - ❖ Motors, generators, energy storage
    - ❖ Power electronics
- Thermal management
  - ➢ Low operating temperature
    - ❖ Large space claims
    - ❖ High power demand from the engine/generator
- Silent Watch requirement
  - ➢ Energy storage shortfalls
  - ➢ Control strategy and limited power budget
- Onboard Exportable power
  - ➢ Clean power for Tactical Operating Centers (TOC)
  - ➢ Power supply from mobile platforms for other applications

High Power density motor

SiC MOSFET



Phase change cooling



Li-Ion Battery Pack

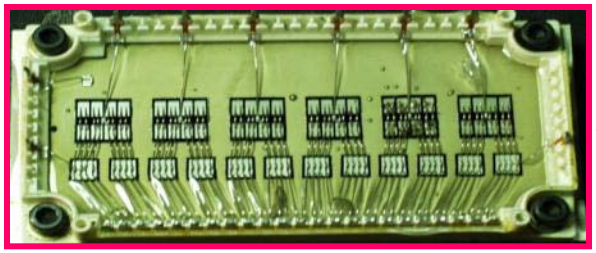
Tactical Operation Center (TOC)

Hybrid Electric Component Program

- Traction Motors

- Energy Storage
  Li-Ion

- Power Electronics/cooling



- Vehicle tests:
  - ATC
  - AAEF

Thermal Management

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Technology Goals

FY	01	02	03	04	05	06	07	08	09	10

Prime Power (kW/kg): 0.3 → 1.5 — Engine — 3X

Energy Storage (W-hr/kg): 45 → 200 — Lead Acid — Li-Ion Batteries — 4X

Motors (kW/l): 3 → 10 — Traction — In-Hub — Field Weakened PM Motor — 3X

Power Conditioning (kW/l): 0.75 → 6 — Si dc-dc Converters — SiC dc-dc converter — 6X

Pulse Power (J/cc): 0.67 → 2.5 — Capacitors — Solid State Output Switch — 4X

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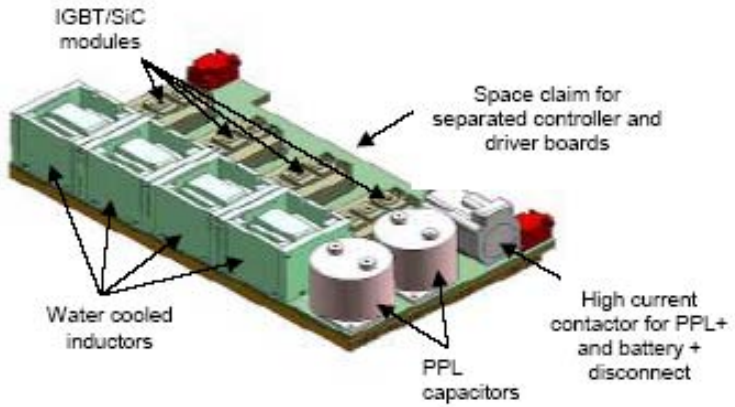
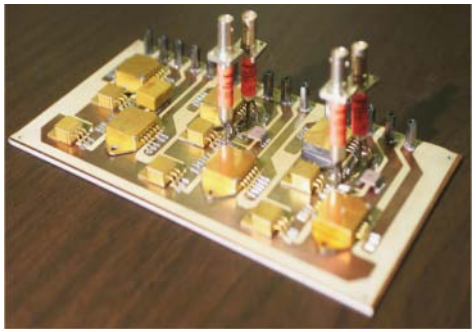
Power Electronics

- Thrust is SiC to overcome:
  - Thermal issues
  - Efficiency
  - Low frequency requiring large capacitors
  - Low power density

Approach: Develop power devices using SiC diodes as an interim step
Develop All SiC motor drives and DC-DC converters as the device technology matures



100 kW Si/Si-C hybrid DC-DC converter



All-Si-C motor-drive inverter

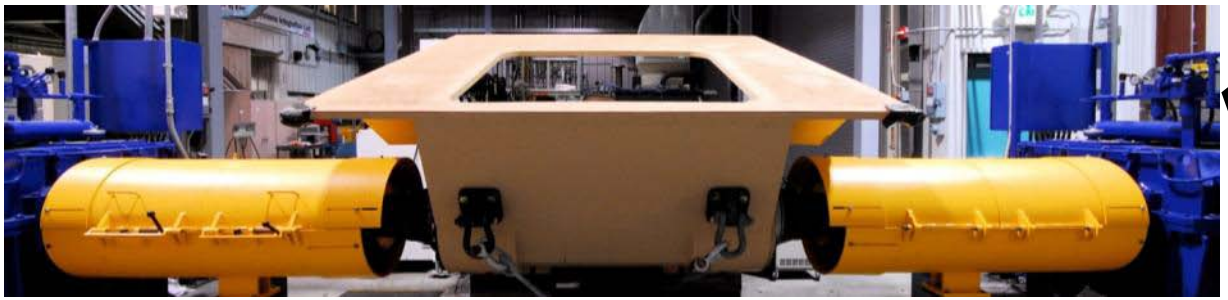
SiC PiN Diode Module

Power and Energy SIL

The SIL provides capability to accelerate the integration and maturation of critical FCS MGV system technologies in order to meet FCS Performance within the weight and volume constraints

System Integration

System integration into vehicle platform



HOTBUCK platform with FCS hardware

Hybrid Electric Vehicle Experimentation and Assessment (HEVEA)

Currently there are no industry or SAE standards for measuring the fuel economy of hybrid vehicles in cross country environments.

Objectives

- Develop HEV Test Operating Procedure (TOP) using accepted industry practices and DOE processes
- Determine the fuel economy benefits of hybrid electric vehicles using quantifiable test data
- Develop and Validate TARDEC M&S models

Testing

9 conventional and 7 hybrid electric vehicles are being tested

A. Conventional:
2 - HMMWVs,
2 -21/2T LMTVs
1 - 5T MTV
1 – FMTV CVT
2 - HEMTTS
1 – UV

B. Hybrid Electric:
1 – HMMWV
1 – RSTV
1 - UV
1 – UV
1 – AH/SS MSV
1 – FMTV
1 – HEMTT A3

HMMWV Series HE

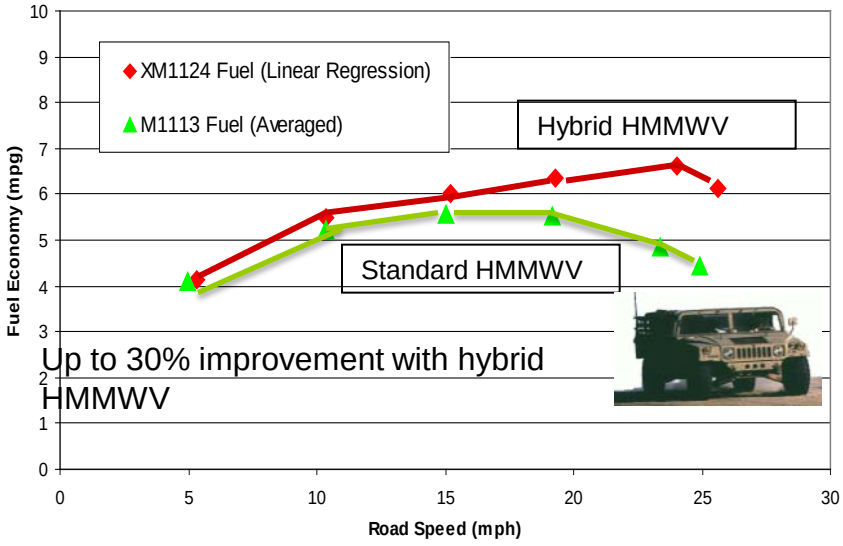
RSTV Series HE

Parallel Hybrid MSV

2 Parallel hybrid UVs

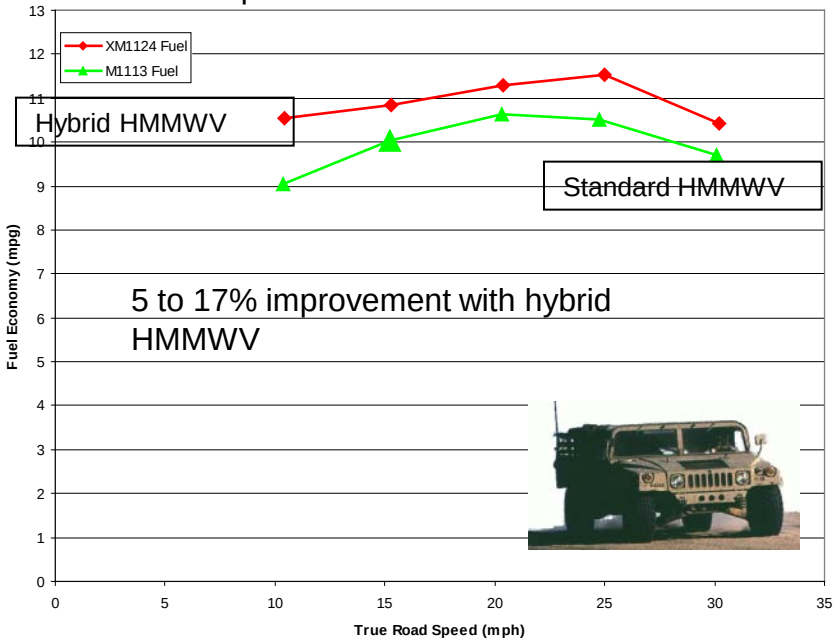
Fuel Economy varies with terrain & driving conditions

Fuel economy comparison on Churchville hilly Terrain



Up to 30% improvement with hybrid HMMWV

Fuel economy comparison on Munson flat paved Terrain



5 to 17% improvement with hybrid HMMWV

HTUF DOD Tech Model

- Proven process to launch commercial production, focusing on user needs
- Over 80 national fleets, including DOD, involved in process
- Eight National Meetings of top truck OEMs, suppliers, fleets
- First 24 Pre-Production Trucks tested & fielded w/in 3 Years; million miles of experience; directly led to commercial production launch
- Military receiving first in-use hybrid field data from geographically dispersed nationwide deployment
- Six fleet Working Groups active, new Construction Equip Forum launching
- Three additional pilot deployments ready

HTUF Industry Contact Point for Dual-Use Heavy Hybrid Technologies

Energy Storage Requirements & Challenges for Ground Vehicles

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Sonya Zanardelli

Energy Storage Team Leader

Ground Vehicle Power & Mobility (GVPM)

Pacing Vehicle Requirements for Energy Storage

There are three distinct requirements for Military Energy Storage:

- ***Starting, Lighting and Ignition***

  Batteries provide electric power to start the vehicle power generation (Engines / APUs)

- ***Hybrid Vehicle Boost Acceleration and Regenerative Braking Energy Capture***

  In hybrid vehicle powertrains, batteries have the ability to supplement main engine power for burst accelerations.

  In addition, batteries can be used to recover wasted energy in vehicle braking

- ***Silent Watch***

  Batteries can provide the energy storage capability to power mission equipment with main engine off while the vehicle is stationary

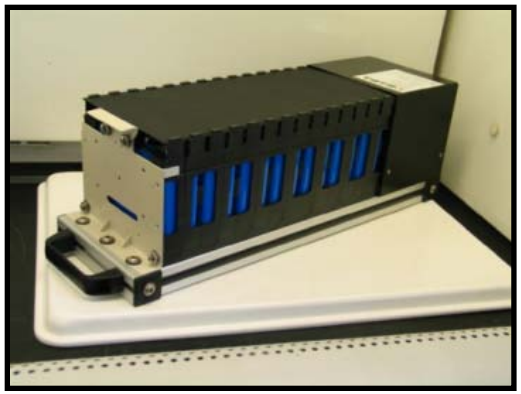
Energy Storage Team Missionn

- **Pursue energy storage technology research, development, component test and evaluation for CURRENT and FUTURE ground vehicle fleet**

- **Identify technology barriers and develop technical solutions**

- **Provide technical support to customers, other teams and government agencies in all energy storage**

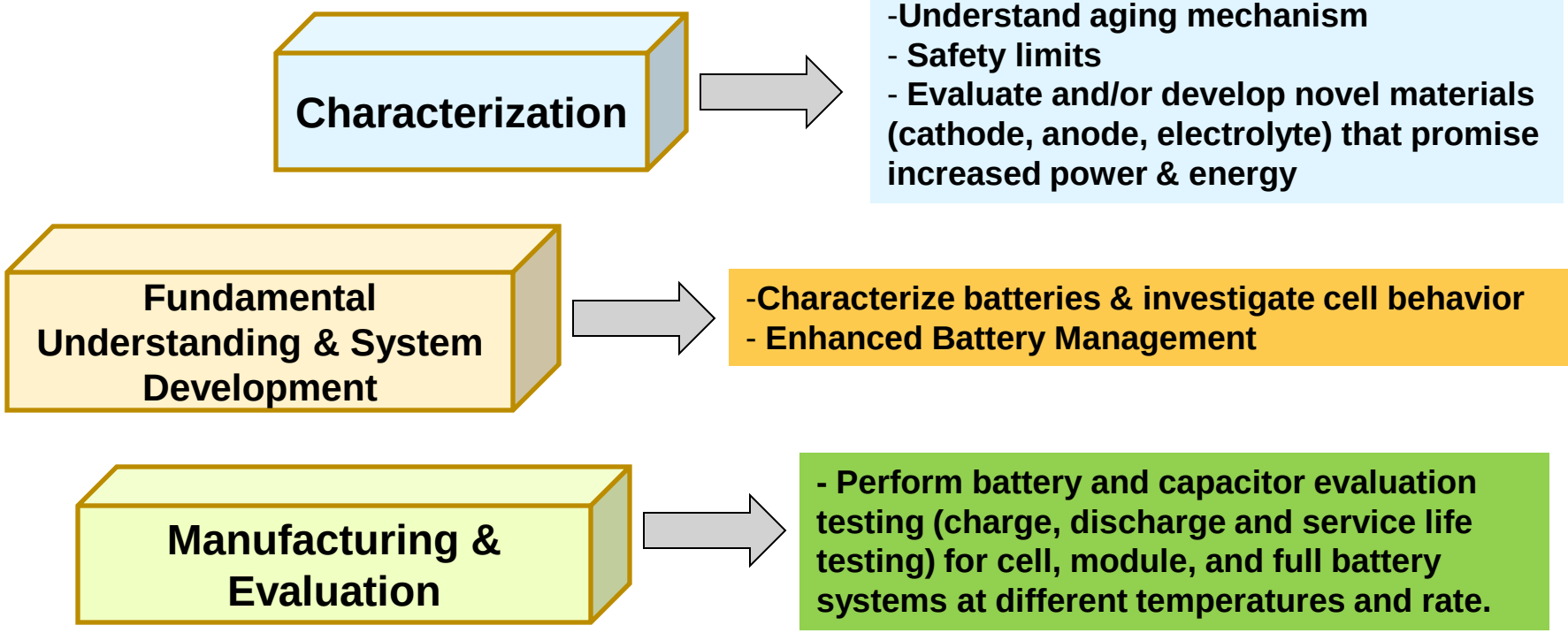
Battery Technology Evaluation Lab



Module Test & Eval

Cell Test & Eval

Energy Storage Focus Areas



Ongoing R&D:

- **Focused investigations on novel materials (cathode, anode, electrolyte) for increased power and energy & reduced cost**
- **Develop advanced diagnostic tools and battery management system.**
- **Develop and apply advanced models for batteries and components**
- **Advanced battery design techniques**
- **Advanced battery manufacturing techniques**

Energy Storage

- Power vs. Energy trade-off design optimization.
- Manufacturing process development and cost control.
- Thermal management.
- Cell & system safety & reliability.
- System control & cell and battery management systems.
- Alternative electrochemical improvements.
- Thermal runaway process and its control.